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Published
With international search report.

(54) Title: IMPROVED METHOD AND APPARATUS FOR CREATING SOUNDS IN A VIRTUAL WORLD

(57) Abstract

A method and apparatus for creating sounds in a virtual world. The system provides signal processing capabilities to convert monaural sounds to fully spacialized sound sources. A user of the system wearing a pair of stereo headphones perceives live, computer generated, or recorded sounds as coming from specific locations in space, just a listener does in the real world.

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+ Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

IMPROVED METHOD AND APPARATUS FOR CREATING SOUNDS IN A VIRTUAL WORLD

BACKGROUND OF THE INVENTION

This invention relates to virtual reality systems and, more particularly, to a method and apparatus for creating sounds in a virtual world.

Users of computer systems are now able to create virtual realities which they may view and interact with. One type of virtual reality system is disclosed in U.S. patent application No. 535,253, filed June 7, 1990, entitled "Virtual Reality Network," the disclosure of which is incorporated herein by reference. One task which must be performed is the creation of the virtual worlds within which the users interact. The virtual world should simulate the real world as closely as possible. Thus, not only must the animated world be created, but the sounds which one would expect to exist in the virtual world must also be provided.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for creating sounds in a virtual world. The system provides signal processing capabilities to convert monaural sounds to fully spacialized sound sources. A user of the system wearing a pair of stereo headphones perceives live, computer generated, or recorded sounds as coming from specific locations in space, just a listener does in the real world.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a particular embodiment of an apparatus according to the present invention for creating sounds in a virtual world.

BRIEF DESCRIPTION OF THE APPENDICES

Appendix 1 is a text description of an apparatus according to the present invention for creating sounds in a virtual world;

Appendix 2 is another text description of an apparatus for creating sound in a virtual world; and

Appendix 3 is a source code listing for a program used for creating sounds in a virtual world.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Fig. 1 is block diagram of an apparatus for creating sounds in a virtual world. A more detailed description of the apparatus shown in Fig. 1 appears in Appendix 2. The following describes some of the capabilities of the system.

AudioSphere contains several innovations, including:
1:Acoustic touch feedback using spatialized acoustic cues for "Grab/Hit/Unhit"
2:Simulated and exaggerated Doppler shift cues using MIDI PitchBend;
3:Parallel processing architecture, where rendering and other computations happen in a separate processor, connected to the host by a low-bandwidth channel
Another item: MIDI-based generation of real-time sound effects in VR. This item is a prerequisite for 2, and a subsystem in our implementation of 1 and 3, but MIDI sound in VR as such may be too general and obvious a method for any specific patent claim.

1: Touch Feedback
Touch feedback is a valuable element of computer/human interface, particularly when using the hand to grab simulated or "virtual" objects, as with hand-measuring devices like the VPL DataGlove. The present invention uses sound rather than tactile feedback to indicate correct gesture for grabbing objects (Grab), actual contact with a

grabbable object (Hit), and release of a previously Hit object (Unhit or Release). In our implementation, the sound is three-dimensionally rendered and appears to come from the user's hand, but that need not be a requirement of the patent claim. Also, MIDI control of digitally sampled sound is our synthesis method, but that should not be a prerequisite of the claim.

In our invention, sound feedback indicates several things:
Grab: whether the current hand gesture allows the object to be picked up (Grab gesture). In the current implementation a grab gesture results in a continuous sound that continues until the hand intersects with a grabbable object. We use a sound of continual suction sound, "sssss", to indicate the hand's potential for picking up an object. This suggests a "vacuum suction" model of picking up objects, rather than closure of the fingers around the object, and helps the user make a correct assumption about the user interface.
Hit: whether the hand has intersected with the object to be picked up (Hit) object can be grabbed now. In the Virtual Reality system, motion of the object now follows motion of the hand. The Hit sound can be continuous until the object is released, but in the case of the vacuum suction model, the sound is "ssssp!" Another sound can continue while the object is being held, although in a system with other feedback (e.g., graphics) this is not necessary.
Unhit: whether the Grab gesture has ended and the currently held object has been released. If the vacuum suction model, we use a sound of reverse suction, again followed by silence: "Psssss."

2: Doppler Shift
In the physical world, Doppler shift is the increase or decrease of the pitch of a sound in accord with the speed of the object (rate of change of radial distance) relative to the listener. When a listener and object move *toward* eachother, the pitch of a sound emanating from the object *goes up* when heard by the listener. When they are moving away from eachother, the pitch goes down. The amount of pitch change is proportional to the fractional speed (rate of change of radial distance) of the objects relative to the speed of sound (about 600 miles per hour at common earth pressure and temperature). Thus the pitch of an object moving toward the listener at 60 mph is raised by about 10%.

AudioSphere, in conjunction with Body Electric and its DM's, generates Doppler shifts by raising and lowering the pitch using MIDI PitchBend capability built in to many modern music synthesizers. On synthesizers with polyphonic pitch bend capabilities, like the EMAX II synthesizer used in the current AudioSphere, several different sound sources can be doppler shifted at once. MIDI provides a low-bandwidth (typically 30 samples per second) method for the host computer and Body Electric to shift pitches of sounds emitted from objects in simulations, virtual reality, and other applications of AudioSphere.

MIDI is a hardware/software standard for generating and controlling sound in real-time on a low-bandwidth channel (31.25 Kbaud). MIDI PitchBend is a 14bit quantity that takes a range of values from 0 to 16,383. The lowest downward bend value is 0 and the highest pitch bend is 16,383, with a middle value of 8192 indicating no bend.

The Body Electric DMs allow the designer to specify the objects that have Doppler shifting, and to create attenuated or exaggerated doppler shifts as objects in the model move. The value for the PitchBend is determined by this formula:

PitchBend = 8192+(ScaleFactor * (Speed / SpeedOfSound))

Speed is computed as the rate of change of radial distance between the object and the ear, using the GlobalDistance DM in Body Electric. Speed is positive when the distance is increasing, negative when the object moves toward the listener. The sign of the ScaleFactor is negative so when two objects are moving toward eachother, the PitchBend value goes up. The ScaleFactor can be adjusted depending on the specific PitchBend response of the MIDI synthesizer, which typically ranges for +-12% to +-200%. The ScaleFactor or SpeedOfSound constants can be set to simulate very rapid motion, i.e. motion over great distances with a correspondingly dramatic pitch shift due to doppler when the object passes by.

Exaggerated doppler shift and exaggerated rolloff of sound loudness with distance may be useful claims in an AudioSphere patent. Sound rolloff can be proportional to the distance, the distance squared, or any other exponent. The "cartoony" exaggerations heighten the VR or other user's perception of space and motion in the application.

3: Parallel processing architecture

AudioSphere uses one or more *peripheral processors* to compute sound parameters for the 3D spatial sound rendering module(s), limiting the amount of computation that needs to be done on the central host running Body Electric. Current AudioSphere code runs on an IBM-PC compatible with a 80386 and 387 math processor. Body Electric sends the peripheral processor cartesian coordinates relative to the head (from the center between the ears). The peripheral processor performs conversion from cartesian (x, y, z) coordinates to the spherical (azimuth, elevation, and radius) coordinates required by the 3D sound spatializer (in this case, the Convolvotron subsystem).

Sending head-relative cartesian coordinates lets the peripheral processor perform the relatively expensive trigonometry without taxing the host processor as much as a uniprocessor system, increasing the real-time performance of the system. At the same time, the head-relative cartesian representation, generated using FollowPoint DMs in Body Electric, simplifies the computation in the peripheral processor, which does not need an ongoing model of the head's coordinates in the world, only of the fixed distance between the ears and the filtering properties of the head.

While the above is a complete description of a preferred embodiment of the present invention, various modifications may be employed. Consequently, the scope of the invention should not be limited except as described in the claims.

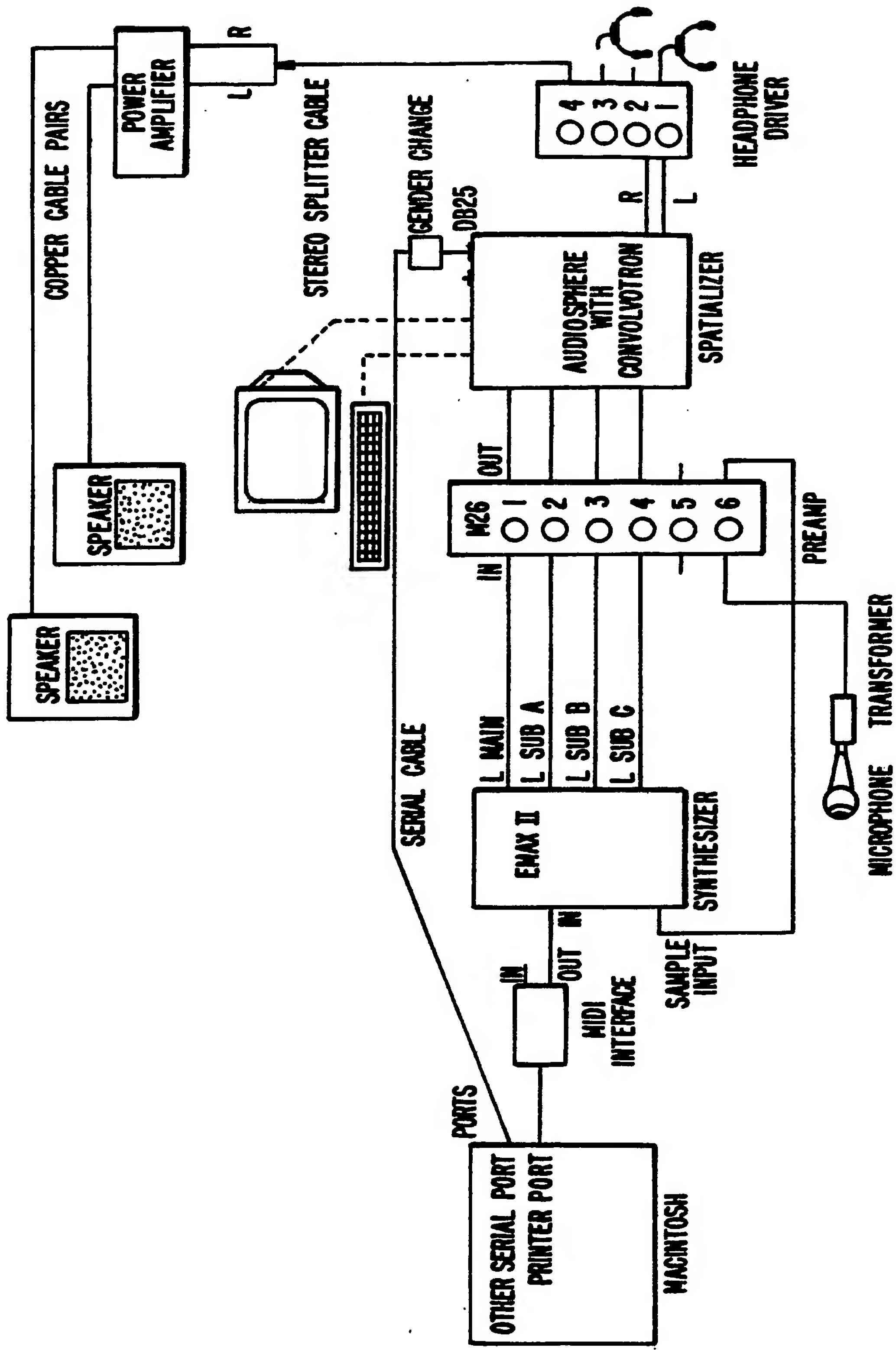
WHAT IS CLAIMED IS:

1. An apparatus for creating sounds in a virtual world comprising:

coordinate means for providing cartesian coordinates of a sound-producing object located in a virtual world;

transform means, coupled to the coordinate means, for transforming the cartesian coordinates to polar coordinates; and

sound generating means, coupled to the transform means, for generating a sound which is perceived as originating from the cartesian coordinates in the virtual world.



COPPER CABLE PAIRS
POWER AMPLIFIER
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STEREO SPLITTER CABLE
GENDER CHANGE
DB25
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HEADPHONE DRIVER
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AUDIOSPHERE WITH CONVOLVOTRON
SPATIALIZER
SPEAKER
SPEAKER
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M26
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IN
PREAMP
L MAIN
L SUB A
L SUB B
L SUB C
TRANSFORMER
MICROPHONE
SERIAL CABLE
EMAX II
SYNTHESIZER
SAMPLE INPUT
IN
OUT
IN
MIDI INTERFACE
PORTS
OTHER SERIAL PORT
PRINTER PORT
MACINTOSH

FIG. 1.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/08947

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): G03B 31/00, 15/00
U.S. CL.: 381/1

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	381/1, 340/51, 395/80

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 3,665,105 (CHOWNING) 23 May 1972, See the entire document.	1
X	US, A, 4,817,149 (MYERS) 28 March 1989, See the entire document.	1
P,A	US, A, 5,046,097 (LOWE ET AL.) 03 September 1991, Figures 1-17 and Abstract.	1
Y	US, A, 4,569,074 (POLK) 04 February 1986, Figures 1-11 and Abstract.	1
Y	US, A, 3,932,032 (WEINSTEIN) 13 January 1976, Abstract.	1
P, A	US, A, 5,065,432 (SASAKI ET AL.) 12 November 1991, Figure 2, and Abstract.	1
Y	US, A, 4,048,442 (MANNILA ET AL.)13 September 1977, Figures 1-6 and Abstract.	1

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
18 FEBRUARY 1992	16 MAR 1992
International Searching Authority	**Signature of Authorized Officer**
ISA/US	KRISNA LIM

Form PCT/ISA/210 (second sheet) (Rev.11-87)

International Application No. PCT/US91/08947

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, A, 4,524,451 (WATANABE) 18 June 1985, See Abstract.	1
P,A	US, A, 5,052,685 (LOWE ET AL.) 01 October 1991, Figures 1-7 and Abstract.	1
A	US, A, 3,860,752 (ADLER ET AL.) 14 January 1975, See Abstract.	1
P,A	US, A, 4,991,219 (ISENHATH) 05 February 1991, See Abstract.	1
Y	US, A, 4,453,809 (HILL ET AL.) 12 June 1984, See Abstract.	1

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3. ☐ Claim numbers____________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.